Soldering, Brazing & Welding

A Manual Of Techniques

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1 WHAT IS WELDING?

To weld is to join two pieces of metal together. Further clarification of fundamental variations is necessary of course, which then denies a simple definition.

It can just involve pressure, but this is usually aided by some form of heating and varies from the blacksmith's fire weld to electrical resistance spot welding. Heating is also used to enable bonding to occur when soldering or brazing and to melt the metal in fusion welding. Heat energy sources can be

A typical welding situation

electrical, chemical, mechanical, light and sound.

So welding can be done hot or cold, with or without pressure and with or without melting, with or without filler addition, manually or automatically and so on, but it will certainly involve the joining of metal!

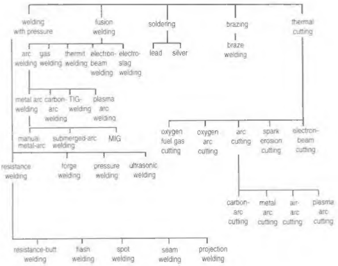
Welding is typically chosen for metal joining because it offers strength and permanency. However, in some cases these features may be undesirable and in others there may be an easier method.

Mechanical devices such as bolts, set pins, screws and so on offer some alternatives which are typically fairly easy to apply, and can be taken apart/reassembled easily, although they may perhaps lack the strength or the ability to retain fluids that welding offers.

Welding is rarely a recreational pursuit, but a means to an end (which may be recreational!), and it is relatively expensive and requires much practice to be done skilfully. It will only be adopted once all alternatives, too many to list and detail here, have been given adequate consideration.

WHICH WELDING PROCESS?

This book assumes of course that welding has been chosen as the most appropriate



Some of the more common welding processes.

joining method but now a particular welding process needs to be selected. Again advantages and disadvantages are weighed against each other to establish the process with the optimum features for the task.

A British Standard lists over ninety different welding techniques/processes many of which are automatic or used in limited special situations.

This book deals with the common techniques in widespread use which require manual skill.

Features of Processes/Techniques

1. **Lead soldering** Quite easy, especially on thin/light joints, good for dissimilar metals/thicknesses, low cost equipment. Relatively low strength.
2. **Silver soldering** Excellent with copper or brass but quite expensive.
3. **Brazing/braze welding** As soldering, but high strength and probably needs oxy-acetylene equipment. Less distortion than fusion processes.
4. **Oxy-acetylene** Gas welding; very versatile for heating, cutting, brazing and so on; high skill level – co-ordination of both hands needed.
5. **Manual metal arc (MMA)** Good for thick and dissimilar metals but tricky on thin metal and in acute corners.

6. **Metal inert gas(MIG)** Establishing optimum welding parameters needs much skill but it is easy to use, versatile and fast over a wide thickness range.

7. **Tungsten inert gas (TIG)** Needs much skill and is slow, used for high quality 'specialist' welding.

Weldable Metals

The ease with which a metal can be welded is known as its weldability and varies greatly.

All metals can be welded, with mild steel being the most common and readily weldable by all methods. Metals with high thermal conductivity require a high heat imput and metals with refractory oxides need stronger fluxing. Some metals need special treatment because they are crack sensitive, and cast-iron especially may crack because it is very brittle.

The least success is experienced with very low melting point alloys, particularly when the exact composition is not known, and commonly alloys which are zinc based.

Any thickness of metal can theoretically be welded but for practical purposes fusion welding below about 0.9mm is difficult, and above 25mm (1in) warrants special consideration in relation to suitable consumables, or the need for a faster machine process.

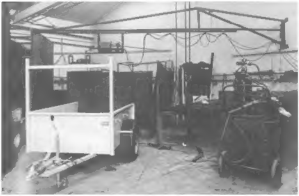
WHERE TO WELD

The classic fabrication workshop is constructed entirely of steel and concrete, with very minor quantities of combustible materials in the form of electrode cartons etc.

For the working environment to be safe, the planning of any welding operation demands to a greater or lesser extent attention to the following.

The Workshop

1. The flammability of the fabric of the building.



A fabrication workshop producing trailers.

Fire extinguishers, an essential part of the welder's kit.

2. The storage/location of flammable items.
3. Location of fire extinguishers.
4. Adequate access for emergency services.
5. Installation of welding and other electrical equipment with particular reference to the loading on the system and ensuring that all metal is at earth potential (earthed).
6. Fume extraction at all welding sources.
7. Adequate screening between arc welding and other personnel.

The Personnel

1. Knowledge of the safety policy and its procedures including the fire drill and evacuation procedure;
2. Basic first aid knowledge;
3. Training in welding health and safety.

Basically the operator needs to know how to prevent accidents, in particular those peculiar to welding, and how to deal with them should they arise.

Finally, on an electrical note, a single phase supply is perfectly adequate, but does restrict the size of welder that can be run on the supply. For faster welding of heavier materials a three phase supply/machine is necessary.

2 NON-FUSION JOINING METHODS

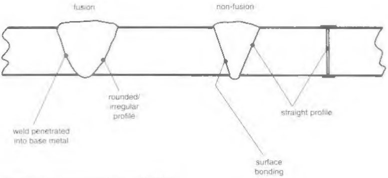
Most of this book is devoted to the making of high tensile joints where the strength is intended to match the parent metal. These are typically made by fusion welding, where the filler wire and parent metal both melt, flow together as a liquid mixture, and on solidifying form a homogeneous joint.

Since it is not always appropriate or possible to fusion weld metals together, the first sections deal with a group of non-fusion joining methods. They are:

1. Lead, or soft soldering
2. Silver, or hard soldering
3. Brazing
4. Braze, or bronze welding

In each of these methods the filler wire melts but the parent metal does not. Joint strength is achieved by 'bonding' or 'skin adhesion' and there is essentially no difference for example between solder and an adhesive, other than the need to heat solder in order to add it as a liquid. In each case a liquid is supplied to the joint which becomes solid and 'sticks' the items together.

The general trend is for an increase in melting point to be accompanied by an increase in tensile strength.



Cross-section through fused and non-fused butt joints.

LEAD SOLDERING

Historically the development of metals started with metals like tin and lead, and progressed to increasingly higher melting point materials which were more useful but more difficult to manufacture. Lead soldering has existed for hundreds of years, and rather than being superseded has become increasingly versatile and varied. It finds application in many alloy combinations, from joints as small as 150 microns on printed circuit boards to lorry radiator joints.

The following factors need to be considered when making a soldered joint:

1. Joint design/preparation
2. Heat source
3. Solder
4. Flux
5. Post cleaning.

Joint Design/Preparation

Surface Contact

Lead solder is weak in tension so soldering two thin edges butted together is unsatisfactory. All joints must be made with overlapped surfaces, where the contact area is made great enough to offset the lack of strength.

In some cases strength is gained mechanically, for example, a wire may be fed through a hole in a terminal and then soldered. This idea is developed in sheet metal joints, which are totally self-secured and where the main function of solder is to seal the joint rather than hold it together.

Fit-Up

The overlapped surfaces must be in good contact. Gaps in excess of 0.25mm cause the solder to flow on each surface but not bridge across the gap. Soldering relies totally on capillary action, that is, the drawing of a liquid between two surfaces very close together, and is much too fluid to bridge gaps or build up like a weld bead. Capillary action can be ensured by using a clamp, vice, weight, press, binding wire or any device that will keep the surfaces in good contact.

Cleanliness

The best results will be obtained by having joint surfaces which are both mechanically and chemically clean, to allow the flux and solder to 'wet' evenly. Oxide and paint and so on can be removed by any abrasive means followed by degreasing with a solvent.

Heat Source

The two components of heat are (a) its intensity and (b) its volume. If bare skin is exposed to a red-hot spark or to a cup of boiling water then the spark has great inten-

Joint design for soldering

sity, and at hundreds of degrees Celsius is very hot; but the boiling water at only 100°C would inflict much more damage, because the volume of heat/amount of energy is so much greater. A change in heat is often required during welding and the decision is always one of whether more heat or hotter heat is necessary.

The heat source options for manual soldering are an iron, a flame, or a combination of both. A range of mass production sources using ovens or electric resistance etc. can be used combined with appropriate techniques.

The joint need only be heated to between 200 and 300°C, which must be supplied in the right volume to enable controlled melting of the solder.

Soldering Irons

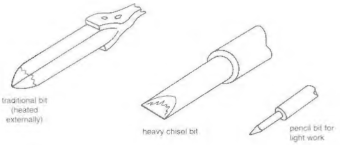
Irons traditionally had a copper bit, but the life of a modern iron is extended by being alloyed or coated with a more corrosion-resistant metal. It is heated either internally electrically or externally with a flame, and physically may vary in section/mass to hold/supply the right volume of heat.

Electric irons are rated in watts, from a 20-watt iron, which is small and suitable for light electrical connections, to a 200 watt iron, which is capable of joining thick sheet.

The shape of the bit is important. For fine electrical work it is pencil-like in section with a raked flat angle at the tip. Heavy sheet joints, on the other hand, require maximum contact so the tip end has large flat sides raked to a chisel edge.

Flame heating is best done in a purpose-made mains gas heater which provides a stable and gentle heat source. An oxy-acetylene (O/A) flame can be used but care is needed to prevent overheating, while a DIY or plumber's blowtorch will heat steadily, if somewhat slowly.

The bit is at the correct temperature when it will melt and hold a small quantity of solder. If too cold it will fail to melt solder, and when overheated solder melts instantly and runs off the bit. Not all irons are designed for continuous use. If overheated or heated for too long the bit oxidizes, becomes unusable and must be cooled and cleaned.



Types of soldering iron bit

Flame Heating

This is best done with a blowtorch, which will heat the work steadily and controllably, assuming the joint has enough mass to demand a flame or enable it to be used without damage to other parts of the component.

If the heating rate is slow then the heat supplied must be contained as much as possible. Placing the work on a firebrick surface rather than steel, working into a 'corner' built up of bricks or, at the extreme, building a brick furnace around the work will help conserve heat.

If it is necessary to resort to oxy-acetylene then the end of the flame furthest from the tip is used with a small nozzle.

This assumes that the work is relatively light but the intensity of O/A can be put to good use on heavy work, as required perhaps by the steam model engineer working in copper.

Joints which are difficult to heat with an iron may still be soldered with one if a flame is used to pre-heat and perhaps maintain a high ambient temperature, so that the heating required of the iron is reduced.

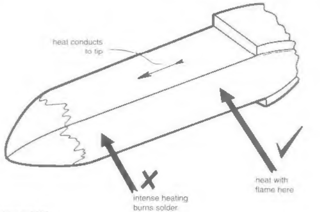
Oven Heating

Soldering can be largely automatic if the joint is preloaded with both solder and flux and placed in a furnace. The temperature of the component can be controlled very closely but it will of course be full heating rather than local.

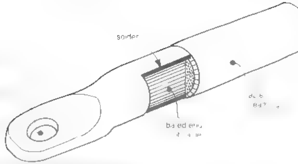
Other heating methods include electric resistance, ultrasonic, induction, hot gas and focus infra-red soldering.

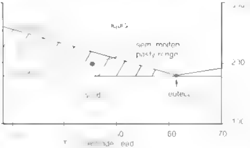
Types of Solder

To appreciate the differences between solders some knowledge of metals and alloys is



Flame heating a solid bit


solder


semi molten
pasty range
200
60
70

Common Solders

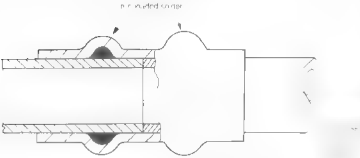
[illegible]

Types of Flux

[illegible]

[illegible]	[illegible]	
[illegible]	[illegible]	Electronic instrument assemblies
[illegible]	[illegible] 188	High class tinsmithing
[illegible]	[illegible]	General purpose copper and sheet [illegible]
[illegible]	[illegible]	Best with flame rather than [illegible]
[illegible]	[illegible]	[illegible] exploiting wide [illegible]

Solder types and their uses



Solder Flux Paste
Prefluxing joints is often a good idea but here solder particles suspended in the flux enable both to be preloaded. Heating now causes the joint to be made 'automatically'.

Post Cleaning
Removal of passive fluxes may be necessary for appearance or because the joint has to be painted. This can be done with organic solvents. Reactive fluxes must always be removed. This is done with hot soapy water and a wire brush.

Making a Soldered Joint

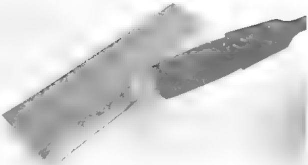
The joint surfaces are cleaned, a suitable flux and solder chosen, and an iron of appropriate size and shape selected. The iron is prepared and heated, the joint 'wetted' and then joined together.

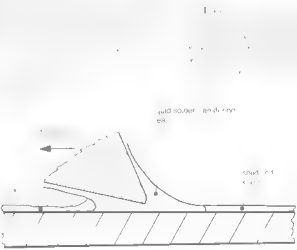
Preparing the Iron
For the iron to transfer solder it must first be coated in solder itself. An overheated iron is prepared by filing down to clean metal, and then the tip is coated in flux, heated and solder applied. Excess solder can be wiped off with a damp rag or sponge which will leave a thin coating, remove flux residue and enable the tip to be checked for complete coverage. If a flame is being used for heating it should be directed to the base of the bit away from the tip to prevent oxidation of the solder.

Wetting the Surfaces
The joint may sometimes be made in a single operation but usually it is much easier if it is done in two stages by coating each surface in solder first, and then joining them together.

The first stage is often inaccurately referred to as 'tinning' and more correctly known as 'wetting' the surface. The technique can be useful when brazing too and ensures that each surface is definitely coated and easily recoverable if it is not before commitment to making the joint.

Once solder has wetted the surface then it is simply a matter of joining solder to solder. Flux is applied to the surface at an early stage to prevent oxidation as it heats. The heated iron loaded with solder is placed on the metal and adjusted to make maximum surface contact. As the metal reaches the temperature of

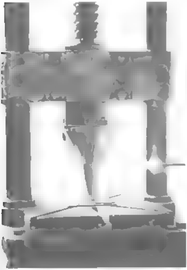




Joining Together

A small amount of passive flux is applied then the surfaces are overlapped and heated until they run together. When heated with an iron it will need to be loaded with further solder to transfer heat and fill any gaps. The iron is directed to one edge of the joint and held in position until the heat has conducted through the joint and the full width is molten. Then the iron is moved along the

Flame heating may speed this process up but heating should not be rushed otherwise the solder layer on the upper surface will oxidize before the lower one has melted. Note that some flux and a further addition of solder are still needed in this second stage.



Flame soldering a funnel under load

Cooling Rate

The best mechanical properties are obtained by fast cooling, which may also remove the aggravation of joints breaking apart because they are weak at high temperatures or have remained molten longer than expected.

Solderability of Common Metals

Copper

Readily soldered with good strength, copper's limiting factors are its high conductivity and the demand for a lot of heat which becomes most noticeable with increase in mass thickness. Colour matching can be a problem.

Brass

These high copper alloys are again easy to solder, with less quantity of heat required than with copper but sharing the same disad-

Steel

Steel is more difficult to solder than copper or its alloys but is quite readily joined with any type of solder. Some coatings like tin or high lead (Terne plate), are very easy, aged cadmium and zinc are difficult, and chrome impossible.

Galvanized Steel

Getting solder to wet with the zinc coating on galvanized steel is quite tricky and only possible when:

1. Concentrated hydrochloric acid is used as the flux. This must of course be handled with care and inhalation of fume be avoided

2 The flux must not be added until immediately prior to its need, because after only a few seconds of exposure to acid the surface corrodes and prevents wetting.

Stainless Steel
High tin content solders provide the best strength and are used in conjunction with highly reactive fluxes and if necessary hydrochloric acid. The metal must be meticulously cleaned both before soldering for the soldering to be successful and after to prevent subsequent local corrosion.

Aluminium
This metal and its alloys can be soldered using purpose made solders and fluxes, but this is not common and tends to be restricted to production technology.

SILVER SOLDERING

[illegible] r soldering [illegible]

classic use is in the joining of brasses a[illegible] copper. Note that cadmium free types [illegible] recommended for items intended for fo[illegible] handling. The actual method for making a [illegible]er soldered joint is exactly as for braz[illegible] and is described in the next section.

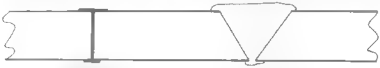
However, for silver soldering the flux m[illegible] be designed for use up to about 650°C. [illegible] prevalent flux is known as 'easy flo', wh[illegible] comes in white powder form.

For the filler wire, the silver content c[illegible] vary between 2 and 85 per cent, but is co[illegible]monly in the range 22–45 per cent. High[illegible] contents perform better but get very expe[illegible]sive, which is offset by the low volu[illegible] requirement of capillary joints.

BRAZING AND BRAZE WELDING

Brazing and braze welding use the same fil[illegible] wire, which has a strength near to that [illegible] steel but a much lower melting point.

Brazing, like all the soldering techniqu[illegible]



braze welded butt

is very local with the flame held close to the work and by careful control of the temperature the filler bridges gaps, corners and Vs, that is, it builds up rather than thinly coating surfaces.

Braze welding is quicker than brazing and may result in less distortion because it is done at a lower temperature, however, brazing can produce an almost invisible joint when cleaned up and does not break or interrupt the joint profile.

Types of Brass Filler Wire

All fillers are primarily brass – a copper zinc alloy – but have a further significant alloying addition by which they are known. The most common is silicon brass, the others being manganese, nickel and aluminum.

Silicon

When metals are cast directly into their finished shape silicon addition improves fluidity, and refines the crystalline structure making the grains sr

Silicon strengthens brass and aids capillary action, so it is a good general purpose wire.

Manganese

This is designed particularly for the joining of cast iron and has good strength, bonding characteristics with this metal.

Nickel

Nickel imparts high strength but is the most expensive alloy addition. Typical applications are attaching tool steel tips to machine cutting tools and joining stainless steel.

Aluminum

Aluminum filler is only used for the joining or repair of aluminum bronzes.

Types of brass	Melting point
silicon	[illegible]
manganese	[illegible]
nickel	[illegible]

Types of brazing wire

Aluminum Alloys

wire, but in fact simply describes capillary joints made above 500°C, with lower temperature ones being made by soldering. Aluminum can be brazed with an aluminum wire, typically with silicon or silicon copper additions, which melt a little below the melting point of pure aluminum.

Types of Flux

A general purpose borax based flux obtained in powder form is used with brass filler wires. The exception is aluminum bronze, which requires a unique flux. Proprietary fluxes are available for a range of applications and are not interchangeable – an aluminum brazing flux is not suitable for fusion welding alu-

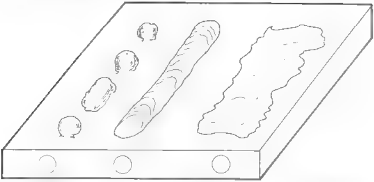
Wires with solid flux coatings or with flux embedded in a serrated surface may be preferred because they enable the joint to be made without interruption.

Heat Source

A blowtorch may provide enough heat to braze smaller items but an oxy-acetylene flame is faster and can be used to braze weld. Brazing requires a neutral heat source but for

Brazing Technique

Braze Welding Technique

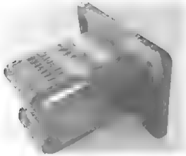


Under and overheating of brass weld beads

Dissimilar Metals

Cast Iron

Malleable Iron



A braze weld [illegible]

Mild Steel

Coated Metals

3 OXY-ACETYLENE WELDING

satile compared to that of other welding processes and finds use in the ways described

USES

Fusion Welding

The flame is directed at the joint edges until each melts and the two flow together. On removal of the heat the material remains united

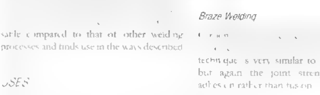
Brazing

Braze Welding

technique is very similar to fusion welding but again the joint strength relies on adhesion rather than fusion

Silver (Hard) Soldering

A plumber's blowtorch is often adequate but the oxy-acetylene torch is superior for close control on small tasks or for providing



The hottest part of the flame

enough heat on very large ones.

Lead (Soft) Soldering
The oxy acetylene flame is too intense a heat source in all but the most expert of hands but it can still be very useful. Items with a lot of mass or ones designed to lose heat such as car radiators can be readily preheated to speed up the soldering operation and sometimes are most easily completed with the

Thermal Cutting
By exchanging the welding head for a cutting attachment steels can readily be cut with ease and speed through great thicknesses.

General Heating
Whilst the oxy acetylene torch is designed primarily for welding and cutting it provides an extremely useful source of heat for alternative uses. Some examples are:

1 Heat treatment of items such as chisels
2 Local heating of metal in order to cause it to bend more easily and at the desired

3 Heating of items to expand them in order that they produce a contraction fit

Heating a cut and shut angle iron notch

on cooling or perhaps to fracture corroded bonds between components, for example on car exhaust systems

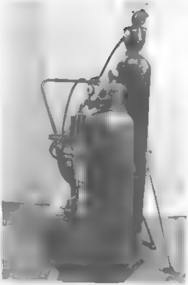
EQUIPMENT REQUIREMENTS

Oxygen

Oxygen for industrial purposes is always contained in alloy steel cylinders, painted black. BCGA codes of practice demand that all cylinders meet certain criteria, in practical terms, for welders this means that the cylinder is labelled with the type of gas, and the pressure it is charged to when full at 15°C. This information can also be found stamped onto the cylinder near its neck, along with its tare weight, serial number and so on

Cylinder Pressure and Contents
In the past decade average cylinder pressures have risen from 175bar to 200bar, and depending on the supplier may soon change to 230bar. This has implications in the use of regulators since older ones are unlikely to be able to cope with these high pressures. At 200bar a standard large cylinder contains 9,660 litres of oxygen.

Oxygen has no smell, taste or colour that would make it easy to detect. Whilst it does not burn it is potentially extremely dangerous. Oxygen has to be present in order for things to burn, but it may not be readily recognized that by increasing the oxygen content of the atmosphere, burning is much more spontaneous and vigorous. This effect is disastrous when, for example, oxygen leaks in a confined space, but of course is put to good use in the controlled situation of an oxy acetylene flame where further oxygen can be added in order to improve combustion.



Typical oxy-acetylene welding equipment

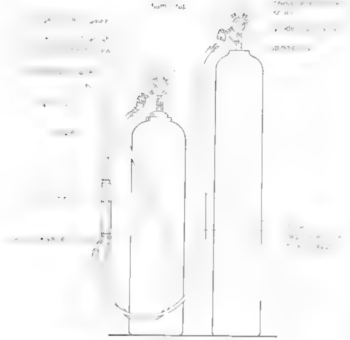
Acetylene

Like oxygen, acetylene is supplied in a variety of cylinder sizes, from very small 'portapak' ones to the large ones designed for manifold systems. Acetylene is always supplied in steel cylinders, painted maroon, which are shorter and larger in diameter than their oxygen counterparts. The cylinder will again bear a label identifying its contents, and giving pressure, weight, year of issue and so on.

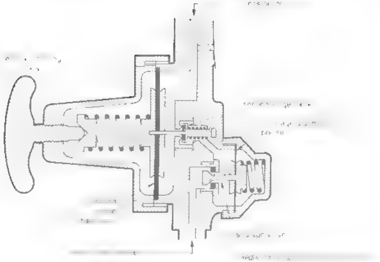
Cylinder Pressure and Contents

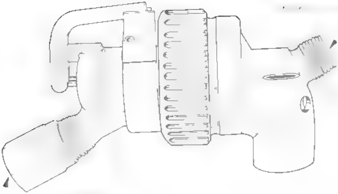
Acetylene cannot simply be pressurized like oxygen because it becomes very unstable – if

Cross-section through an acetylene cylinder


acetylene
oxygen

Gas Pressure Reg[illegible]





ocedures,

of more

or leak at a delivery pressure of 0.6bar

Gas Hoses

Gas hoses provide a means of flexible delivery of gas from the regulator to the welding torch and vary in the following ways.

Size

Length

The standard length

doubled or may get

Fittings

move up and down a short cham

one way it allows gas to flow on

explosion at the welding tip, ser

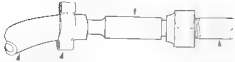
back and cuts off the gas supp

vides a high degree of safety and

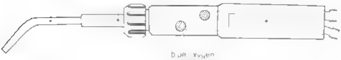
does not remove the need for

Torch

Shank



Identifying a hose-check valve



Mixing Chamber

The controlled gas supply flows on through the shank and into this unit, where the gases actually mix together. This small, complex item is made of brass, perhaps chrome plated, and is screwed onto the end of the

Nozzle

This is made of copper and is screwed into the end of the mixing chamber. Since copper is a fairly soft metal it can be damaged quite easily. The threaded end will not screw in or seal properly if the end is damaged and the flame at the other end will be distorted and lack focus if it suffers damage.

Nozzles are identified with a number, which indicates their consumption of each

Identifying a No. 2 nozzle

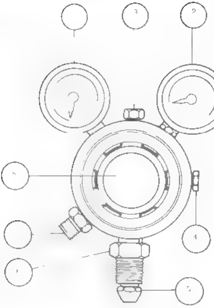
OBTAINING EQUIPMENT

Gas Supply

Gas can be obtained from a supplier. Most should offer com[illegible] and provide good service [illegible] information on all aspects including the handling, transport and use of industrial gases.

Regulators

[illegible]



1 Outlet pressure gauge
2 Cylinder pressure gauge
3 Pressure control valve
4 Plug
5 Regulator inlet
6 Inlet [illegible]
7 Regulator [illegible]
8 Label giving gas inlet and outlet pressures

A tw[illegible]

will be one made to BS 5741/BS 7650 in the UK, or equivalent, which should be evident on the body of the regulator. It must be capable of handling the pressure of a full cylinder, for oxygen this would be 200bar.

Flashback Arrestors/Hoses

There are three types of arrestor as discussed above but beyond this there is very little variation. Similarly once the size/length of a hose has been selected then variation in price

supplier.

Torches

Many designs of torch are available, with variations in weight and small differences in appearance, but all essentially working in the

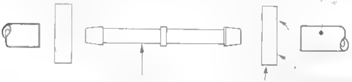
MAINTAINING AND REPLACING EQUIPMENT

Cylinders must be turned off when not in use and when the cylinder is empty prior to removing the regulator. They should be returned for refill before they are completely exhausted, ideally when the pressure has dropped to about 1bar. These precautions will prevent air backfilling into the cylinder.

No maintenance is necessary or permitted on cylinders. If a cylinder is thought to be unsafe in any way, for example if the gland nut at the neck leaks, then return it to the supplier and accept a replacement.

Regulators, flashback arrestors and torches may each cease to perform correctly after prolonged use or time. These items require expert attention and no attempt should be made to repair them. It is customary to have faulty equipment service exchanged, that is, replaced with a fully guaranteed, restored item at a lower cost than purchasing a new replacement.

Hoses require a somewhat subjective assessment regarding their safety. If the first layer of canvas shows, as a result of abrasion or burning, or if the hose is heard to 'crack' when squeezed tightly through 180 degrees in the hand, or of course if it leaks, then repair or replacement is necessary. Hoses must be repaired properly, by cutting out the suspect length, then reconnecting with a proprietary hose connector, held in place with 'o' clips. Anything less than this is likely to be dangerous. If copper is used in repairing the acetylene line, for example, a chemical compound is formed which in time becomes explosive.



A hose connector and fittings

Similarly the chemical reaction between oxygen under pressure and oil or grease or similar compounds must be avoided, and particular mention of this is made on the cylinder label. The reaction here is a spontaneous explosion. When making gas connections no lubricants, jointing compounds or sealers should be used because they are sus...

ASSEMBLING THE EQUIPMENT

Throughout assembly of the components it will quickly become evident that the system is colour coded – acetylene fittings are all red and oxygen fittings are always blue. The exceptions are the cylinders, which are maroon and black respectively.

It will also be apparent that there are two types of thread; those on similar fittings will be the same size and pitch, but threads for oxygen are conventionally right hand, and those for acetylene left hand. Left hand threads on gas fittings of any sort indicate that the gas is combustible.

... highlighted with 'notched' nuts used on all connections, a feature peculiar to acetylene.

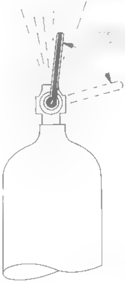
Gas Cylinders

There are two stages in the preparation of cylinders.

First the plastic cap needs to be broken ...

This is done by ... and allowing gas to ... a second before c...

... from the c...



Sniffing a cylinder

Operation of the ... ing on the supplie... opened by turning ...

before using, so that the acetone is allowed to settle in the acetylene cylinder.

Regulators

Although heavy and made mainly of metal, regulators must be treated as precision instruments – only then will they function reliably and give long service. New regulators will need to have the protective caps removed from the threaded gas connections. Older ones should be inspected for signs of damage on the mating surfaces, distortion to the stem, damage to the gauges or indicator needles that do not zero, before reusing. Be particularly cautious with regulators manufactured before 1989, since they may not withstand the cylinder pressure.

The regulator stem is inserted into the cylinder neck, initially hand tightened and then finished off with a gentle hammer tap on the spanner. Consider at this point whether the regulator fouls access to the cylinder key knob and if necessary slacken and rotate the regulator to a more convenient position.

Finally, open each cylinder in turn and purge the regulator with gas. This will also drive through any dust present.

Flashback Arrestors

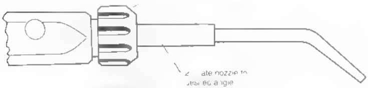
Again remove the dust caps if the arrestor is new, then fit and purge. You will now know if it was put on the right way around!

Hoses

Fit, ensuring each hose check valve is at the torch end, and purge. If the hoses are bonded together then split them before fitting so that they will be quite separate when used.

Torch

Fit and purge, then select and insert a nozzle to suit the work in hand. If at this stage the nozzle points at an angle which makes it awkward to use, slacken the mixing chamber connection, rotate the nozzle to the desired angle and retighten the mixing chamber connection.



Testing

either faults or needs further tightening

LOCATION OF EQUIPMENT

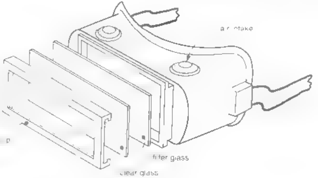
It is too dangerous to allow the cylinders to stand freely so a method of restraint is nec

GAS WELDING ACCESSORIES

Welding Goggles

These are absolutely essential in order to see the welding operation clearly without eye strain and without sparks and spatter enter

through a coloured filter glass which reduces the brightness to a comfortable level. These are made to BS 679 or similar standard



because they have a hinged filter glass which lifts up to expose a clear glass, but all goggles are made to BS 1542 or equivalent.

Protective Clothing

A number of factors determine what protective clothing is needed. A minor task, done on the bench, undertaken in 'old' clothing may not warrant any further consideration. Protective clothing will, however, be a major consideration if welding overhead whilst beneath a motor vehicle. In this case a cap would be necessary in addition to the usual overalls and gloves. Cotton clothing without any frays is best for combating welding sparks, which despite the most vigilant efforts will still tend to find their way into socks, up sleeves and down necks. Beware

Flame ignition

kept in a pocket during welding.

Fire Extinguisher

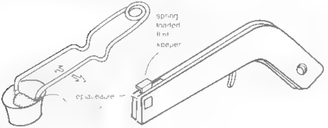
The need to have one of these always to hand during any welding activity must be self evident. Consideration should, however, be given to the type.

Water is excellent and reduces the likelihood of further ignition but is not a wise choice when working near to electrical equip-

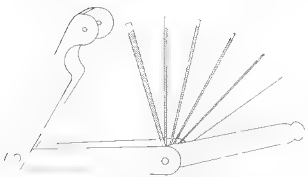
Other possibilities are CO_2, Foam, and BCF, each having its own merits and disadvantages.

Nozzle Reamers

During use the welding flame may become distorted or forked because some spatter has got lodged inside the end of the nozzle. Nozzle reamers are a pack of ridged cleaners



Nozzle reamers



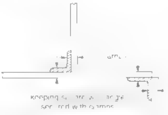
Clamps

Since welding involves holding two or more pieces of metal together and heating them up, some sort of clamping system is often necessary both to aid initial assembly and to hold the pieces in place during welding. Of the myriad types of clamp available, G-clamps and mole grips will find much use.

PREPARING THE WORK

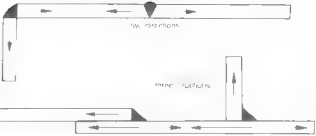
excess oil, grease, paint, soil or rust. Cleaning with an angle grinder or a pedestal grinder may be necessary if the surface is badly cor...

The components need to be held together well enough not to move unduly when tacking or welding, and the clamp, grip or whatever you are using, must be capable of withstanding welding heat. If possible assemble the whole job so that each component helps hold another in place during assembly and so that the appearance of the finished job can ...



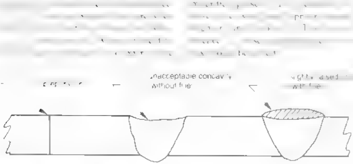
...assembly aids

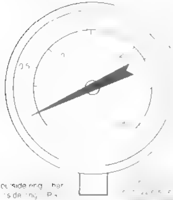
Selecting the Nozzle



Selecting the Filler Wire

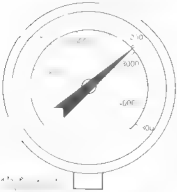
Selecting the Flux





Turn On Cylinders

Adjust Gas Pressure



Lighting the Flame

[illegible]	[illegible]	gas consumption		gas pressure oxygen and acetylene	[illegible]
			ft³/hr		
[illegible]	1	[illegible]	1		
	[illegible]	[illegible]	2	2 [illegible]	
	[illegible]	8[illegible]	3		
[illegible]		140	5	0.14 ba[illegible]	
		200	[illegible]		

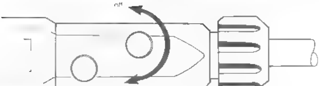
[illegible]

The Neutral Flame

[illegible]

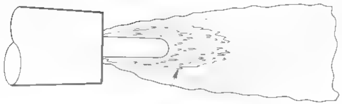
The Carburizing Flame

[illegible]



[illegible]

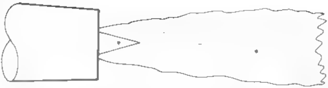
clearly defined inner cone



feather

Applications of Flame Types

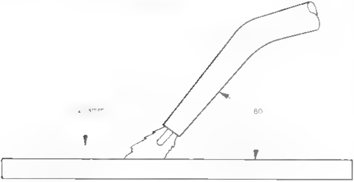
The Oxidizing Flame

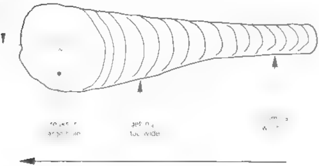


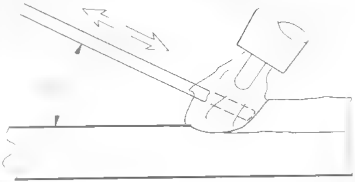
Making a Weld Bead

Without Filler

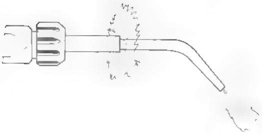
With Filler


60

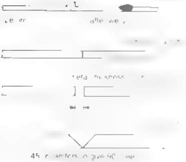

too wide



Beads on plate with and without full penetration



Shutting Down Procedure



2 A butt weld preparation

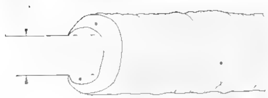
Tacking

MAKING GAS WELDED JOINTS

Butt joints

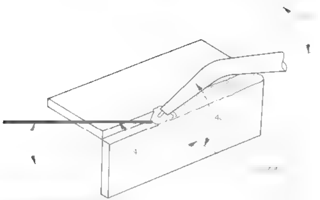
Making a Close Square Butt Joint

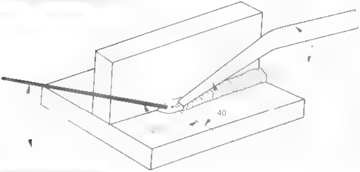
Making an Open Square Butt Joint



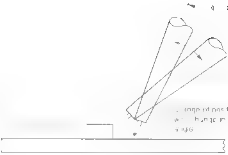
Outside Corners

Inside Corners and T Fillets

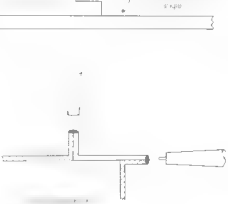




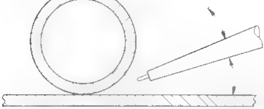
Lap Joints



Torch angles



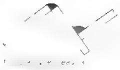
Torch angles

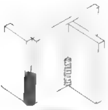


Gas Welding Variables

Size of Material

Position of Weld



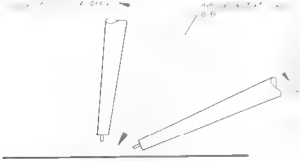


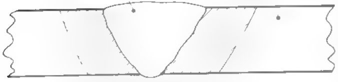
Type of Material

Type of Joint

Torch Angles

Speed of Travel





Filler Wire Size

Filler Wire Angles

Technique

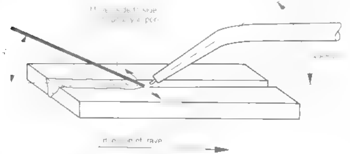
leftward technique used by a right handed ... ding from the right towards the left of the joint. A left-handed person would weld towards the right, so the leftward technique essentially means that the flame points in the direction of travel and is preceded by the filler wire.

Welding of metal over 5mm thick can be greatly speeded up by using the 'rightward' technique but the prevalence of arc welding for such thicknesses has outdated this m

Other Factors

OXY ACETYLENE EQUIPMENT - SAFETY DEVICES AND PRECAUTIONS

This section should be read and its c understood before starting to use the ment for any purpose whatsoever. I sented at this point rather than the the chapter because it is necessar familiar with the equipment and how tions before the safety devices it cont safe usage can be fully appreciated.



Torch and filler angles for the rightward technique

...threaded connection could lead to a spontaneous explosion as the joint is tightened.

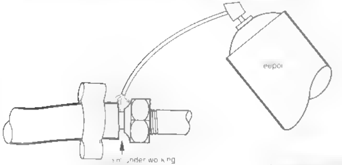
If you want to live long enough to become a good gas welder do not ignore this section.

Cylinders

1 The acetylene cylinder may have a safety ...

10 Close ...
a Moving ...
b Work...
c Cylinder...

Regulators



Testing ...

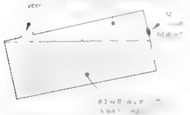
Flashback Arrestors and Hoses

Using the Equipment

Coated Metals

Materials coated with pai... chrome or cadmium can p ocue... toxic or simply irritate the lungs... zinc is a classic example... when welding galvanized steel... and flu-like symptoms. Remove the... use effective fume extraction.

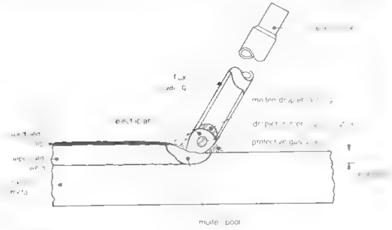
Fuel Tanks



vessel filled with water to make safe

4 MANUAL METAL ARC WELDING

Manual metal arc (MMA) welding [illegible] America and in Britain historically h[illegible]



gap it generates enough heat to melt the electrode and the surface of the metal. The electrode end is propelled by electrical force to the melting metal surface, where it mixes and builds up as the weld bead.

The flux coating on the end of the rod also melts and protects the metal whilst it is molten. It solidifies to become a slag and continues to protect the weld metal as it

THE WELDING CIRCUIT

The following components are the essential features of the manual metal arc welding cir

Source of energy

8 Welding retur

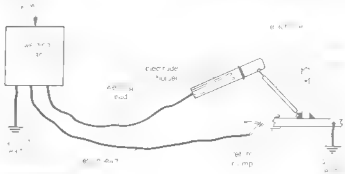
9 Welding eart

Source of Energy

Most welding sets ... from the main ... 24 V ... DIY ... phase supply ... used in fixed ...

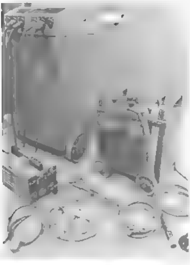
Other welding ... or petrol motor ... site work, where ... readily available

Welding Sets



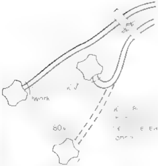
Outpu

Output Current

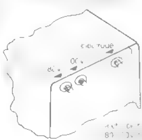


Output Voltage

... trode lead terminal and the ... terminal, which will read 50V ...



Open circuit voltage ... connection



Duty Cycle

Type of Covering

than air cooled types', but being heav y are less portable. They are not as either, because they are akely to need phase electrical supply

Welding Transformers

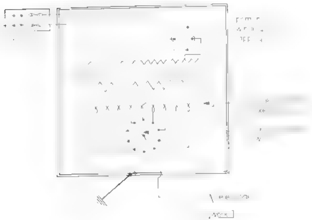
Welding Generators

Welding Rectifiers

also to have TIG welding

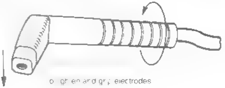
Inverters

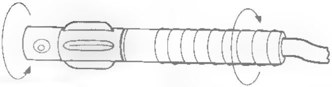
A relatively new developm



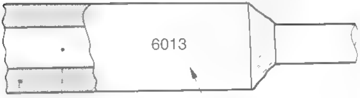
Electrode Holders

Stranded end of a welding lead

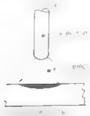


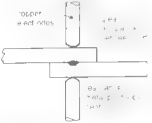


The Electrode



identifying electrodes





name inked on the coating and/or a series of figures which indicates its classification. In the UK 'E4631N.B54H5' is a particular category in BS EN499:1995 whilst '6013' is a very common American coding for general purpose, positional rods.

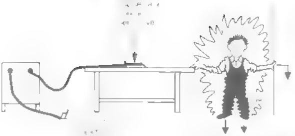
The Electric Arc

The two main ways of using electricity to produce heat for welding are: from electrical [illegible]

The arc in all these processes is the visible evidence of electricity jumping a gap between the end of an electrode and the material being welded. More importantly great heat is produced as the current overcomes the electrical resistance of the gap.

The heat generated is at approximately 4,000°C but will vary between electrodes

OBTAINING EQUIPMENT



accessories thrown in, perhaps. The items can also be purchased individually. The same vendor will also supply electrodes, acting as an agent for one of the many large electrode manufacturing companies. Very small quantities can probably be obtained from DIY stores, but at a high unit cost.

MAINTAINING/REPLACING EQUIPMENT

Welding Plant

Transformers need practically no maintenance and rarely break down because there are no moving parts. Oil cooled types will need the level checked roughly every two years, but could well go for twenty years without needing any topping up. Transformer oil should be used, of course, which unlike mineral oil is electrically non-conductive.

Rectifiers are not immersed in oil and the only maintenance necessary is to take the side/rear panels off and remove the dust build-up periodically by blowing through dry

life expectancy of a rectifier, that is, the length of time that spares can be expected to be readily obtainable is seven years. This is one of the factors influencing the choice between repair of or replacement of the set.

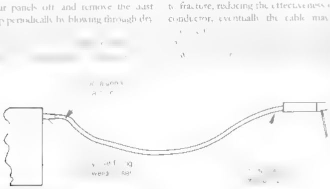
Generators need lubrication of moving parts and renewal of brushes as necessary, along with a supply of diesel.

Welding Cables

Cables for welding are sized in terms of their current carrying capacity, and to avoid overheating they will need to match the maximum output of the welding set.

The protective rubber coating must be checked regularly in order to prevent electrocution or electrical damage to other equipment, and it must be ensured that spatter or hot metal does not burn through the insulation.

After prolonged use, flexing near to either the welding set connection, or particularly the electrode holder, causes the wire strands to fracture, reducing the effectiveness of the conductor; eventually the cable may even

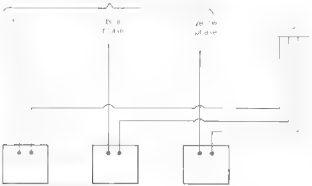


n the welding set and the work the can be lengthened, but this must be th caution. Making a conductor twice also doubles the resistance, which in ables the heating effect. If the cable r used at more than half its capacity should not simply be made longer bu ger in cross-section. This will reduce ating effect and loss of power at the a proprietary cable connectors for

INSTALLATION AND ASSEMBLY

Electrical Supply – Primary Connections

If a portable 40A set is supplied fitte a 13A plug and then placed in a dry, situation, it is ready for use. In industr cation is the fitting of an appropriate pl be governed by company policy and m done by a suitably qualified person.



Welding Circuit – Secondary Connections

Once the welding set is safely installed then the welding operator can make the following ... as necessary

1. Electrode holder to welding lead. The bared end of the lead is invariably clamped in position with a number of Allen screws. Remove the holder sheath and slip over the end. Expose the lead end, clamp in place and slide the holder sheath back over the assembly ensuring no bare metal is exposed.
2. Welding set to welding lead terminal. Bayonet fittings which are pushed into the welding set terminals are fitted in the same manner as electrode holders. 'Lug' connectors are placed over a threaded terminal on the welder and held in place with a nut. The lead is secured to the lug by soldering (see ...

3. Return lead connections. These will be made in the same manner as the welding lead connections but a device needs to be fitted at the work end that enables it to be attached to and removed from the work quickly ...

and magnets. Where all work can be done on a bench then a soldered lug fitting fixed semi permanently to the bench is a cheaper alternative.

4. Establishing an earth. An effective earth should be attached to the work or bench in addition to the return lead. Often the most practical source of earth bonding is the steel frame of the building, but again if in doubt have an electrician sort it out.

MMA WELDING ACCESSORIES

With a supply of electrodes the equipment is

Welding Screens

Face screens are necessary to protect the face from exposure to harmful radiation emitted by the arc. They need to be light and robust, must cover the full face, and carry a filter glass through which the bright arc can be observed.

... one which is hand held. The former leaves both hands free, which is essential in TIG welding, for example. When MMA welding, the free hand may be used to hold a piece of metal in place for tacking, or to hold a ladder or column for stability. Hand held screens are less claustrophobic and less tiring and provide a receptacle for the electrode holder when it contains a 'live' electrode that is not being used.

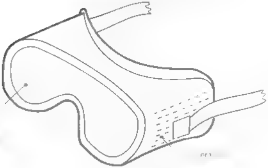
All screens contain a filter glass which reduces the intense light of the arc so that it and the weld pool can be viewed comfortably. The glasses are categorized in BS 679 with higher numbers for darker ones to suit the increased light emitted at high amper...

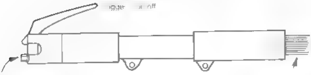
Head shields for arc welding

Chipping Goggles

Chipping Hammers

ng filter, so it is just ... gh in daylight. The ... made specifically





Heating rod

Protective Clothing

The primary concern when welding is not protecting street clothes but protecting the body from the radiation and heat generated by the arc. Ultra violet radiation burns any exposed skin in the same way as very intense sunlight. This exposure may not be direct: light coloured clothing or reflective surfaces like polished metal or white walls must also be avoided. The short term effect can be deep, painful burning, which, like sunburn, may not be fully appreciated until it is too late! In the long term exposure to UV radiation can cause skin cancer.

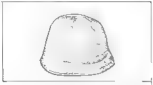
for most work, but the additional protection of a leather apron is highly recommended.

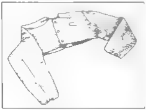
top of the boot: a welder is instantly recognizable by the number of holes in his socks. In extreme cases, such as when heavy arc or gas cutting, leather spats are available to protect the lower legs from spatter burning.

Other Accessories

The same accessories as those required for gas welding will be necessary when assembling metal by any process. MMA tasks tend to be heavier and may therefore require more robust clamps, jigs, hammers and so on.

USING ARC WELDING EQUIPMENT SAFELY




shoulder cape

one dealing with electricity should exer
caution and this must include the
der, who has perhaps 200amps running
ugh the centre of his hand!

ectrocution occurs in one of two ways
completing or forming part of the cir
t or by 'earthing' the circuit. The danger
iod is when the welding set is turned on
t described as being 'live', but before the
is struck. Once the welding arc is under

arc ... rarel
being car
prove me

Assuming that the
properly
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Radia ion

Radiated Heat

Visibl

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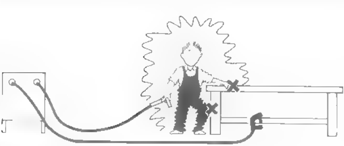
Ar



The spectrum

Visible Light
The light emitted from the arc is so intense that it cannot be viewed without a filter. These are categorized in Britain in BS 679 as discussed under Protective Clothing in

Ultra Violet
Light on this wavelength is filtered out as it passes through any piece of glass. The welding filter glass is coloured primarily in order to reduce the visible light passing through it, but it does also filter out ultra violet radiation as well.

'Arc Eye'
If the arc is viewed with the naked eye then there are both short and longer term effects. Initially the iris contracts to compensate for the bright light to which it is momentarily exposed. The operator may see bright lights or stars, but the view is basically one of darkness, until normal vision is gradually restored over a period of 10 to 40 seconds.

Welding may now continue, without any discomfort or further thought, until some time later the eyes feel extremely painful and as if they are filled with sand. This condition develops about 4–6 hours after the exposure which caused it, often out of working hours.

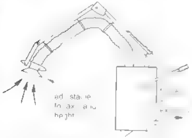
ator from his sleep.

The amount of pain suffered varies with

1 The current being used
2 How close is the arc is observed (over 3m away is 'safe')
3 How long and how many times the eye is exposed to the arc
4 The angle at which light enters the eye entry from the side seems to be worse

To prevent arc eye occurring, the welder must adopt safe working practices, that is, he should always ensure that his eyes are protected by the screen before striking an arc. Due to the very manual nature of the process it is quite easy to strike an arc accidentally.

Operatives working with or near to welding sets are particularly susceptible, because they are not in control of, or perhaps not prepared for welding. All welding areas must have suitable and adequate screening, and are best painted in dark, non reflective colours. Operators assisting the welder must also have a welding screen, or look away at 180 degrees to the arc. Viewing the arc through closed eyelids is both possible and asking for trouble.



A portable fume extractor

Heat

picking up metal is learned

Burns are not only painful in themselves but the heat of the arc on the burns then makes further welding very uncomfortable.

Dealing with Burns

It is important to act very quickly to mini...

extent of turning the flame off and putting the electrode holder down safely. Act quickly but do not cause any further accidents!

2. Run cold water over the burned area. This will bring almost total relief from the pain but equally importantly will prevent the burn spreading and becoming much worse than it need be.

3. Continue to keep the burned area under cold water for about 10 minutes, or until the burn can be removed from the water without warming up and becoming painful again.

4. Cover with a clean dressing and a grant ... act before continuing welding. Do not apply ...

5. Of course medical aid should be sought if the burn is extreme.

Heat Exhaustion

Welders can suffer from heat and dehydration in the same way as foundry workers. When engaged in heavy work on a hot day (or in a foundry!), or in a confined space and with a minimum dress requirement, care should be taken not to become too exhausted.

Slag

Much like burns, one moment of carelessness is rewarded with a long period of pain.

Wear chipping goggles!

PREPARING TO WELD

Preparing the Material

Chemically, MMA welding has a high tolerance for oil, paint, oxide and so on, because the fluxing action of the electrode coating is very effective. For high quality welds to be produced, however, or where these contaminants prove to make the weld porous or brittle, the metal must be degreased and ground clean.

MMA welding is generally applied to thicker metals and this may demand suitable edge preparation in order to weld controllably through the full thickness.

Setting up for Welding

The following points will need to be checked before welding can commence:

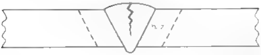
1. Electrode type
2. Electrode diameter
3. Type of welding plant
4. Electrode polarity
5. Voltage setting on welder
6. Current setting on welder
7. The welding earth is in place
8. The return lead connection is made
9. The area is screened as necessary
10. The welding screen with suitable filter is available
11. The chipping hammer and wire brush ...
12. The components are set up and/or clamped together
13. The components are set up on bench

AC DC

DC

EN499

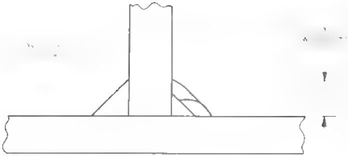
Electrode Direction

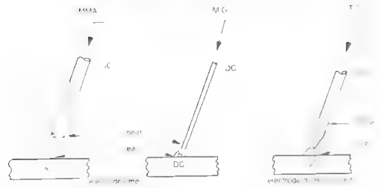


Type of Welding Plant

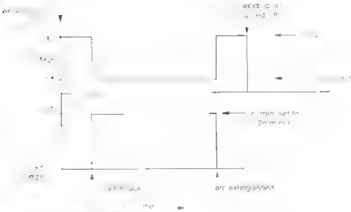
Voltage Setting

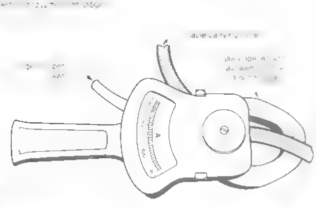
Electrode Polarity

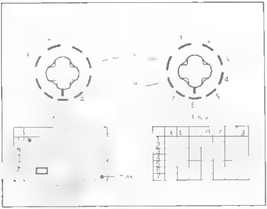


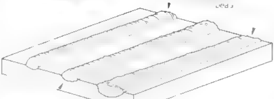

DC
heat
DC

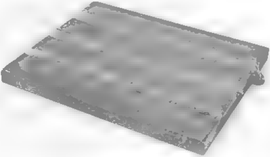
Current Setting








wide low height
beads



MAKING A WELD BEAD

Striking an Arc

The arc is initiated by bringing the electrode end into contact with the parent metal so that current starts to flow through the circuit. The electrode is then raised above the plate surface about 3–4mm and current flows across the gap creating an electric arc with intense heat and light.

The easiest way of striking an arc, with consistent success, is to draw the electrode end through an arc, scraping the plate surface at the lowest point and rising finally to produce the arc length.

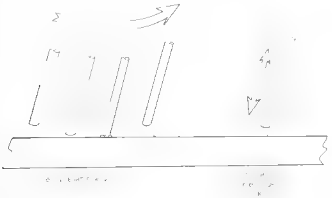
The alternative is to tap the electrode end directly onto the surface and lift it up. Whilst this method can be successful and accurate it is very susceptible to sticking, which in the first method is prevented by the movement along the surface.

If the electrode does stick, t… should immediately be firmly mo… side to side to release it, but bew… flash that will occur at this mome… to respond quickly results in the… resistance heating, which causes… rather than arc is free. If it fails… then the situation is made safe by… welder off, releasing the holder fro… and then removing the electrode.

The sequence when striking an…

1 Place the electrode end abo… above the starting point.
2 Keeping the electrode steady… screen in front of the face.
3 Strike the arc, and in the light… also relocate the starting point.

Difficulty will be experienced at fi… ing an arc at a precise point. This… be developed because weld beads…

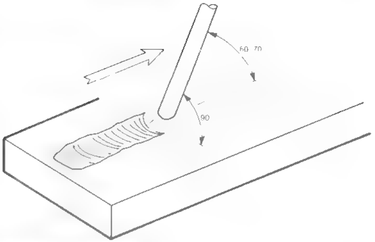


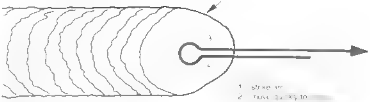
Striking an arc

Common Difficulties in Striking an Arc

Starting a Bead

Continuing a Bead





Finishing Off the Bead

If the arc is simply extinguished at the end of the joint then it leaves a hollow crater which weakens the weld and which may crack as it shrinks on cooling. To fill in the crater:

1 Weld up to the point where the leading edge of the pool is at the end of the joint.
2 Pause for about 2 seconds to fill in.
3 Weld back in the opposite direction for about 5mm without changing the angle of

4 Withdraw the electrode promptly in the new direction.

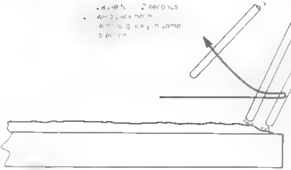
WELD PADDING

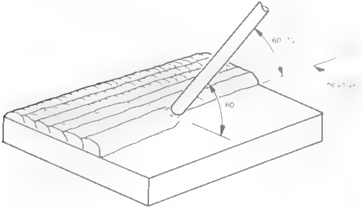
dimensions of 150 × 100 × 10mm, but the bigger the better. The bead should be continuous, extend over the full length, and on completion be deslagged and wire brushed.

The second bead is not placed randomly on the plate but directed at the toe of the previous one, that is, the edge of the weld. The slope of the electrode is still 60 degrees but the tilt (the transverse angle) is now also 60 degrees, rather than the 90 degrees used for the first bead.

The effect of welding in this manner is that half the new bead covers the first one, whilst the remainder laps over new plate. After a number of passes have been made in this way, deslagging between each, the plate thickness will have increased by about 3mm.

It


2 seconds
same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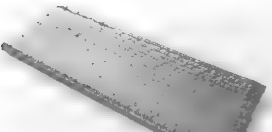


the commencement of each bead. As the plate warms up the beads will become progressively wider and flatter as a result of welding intensively in one area. The aim is for the surface of the weld pad of overlapping weld beads to be as flat as possible so that machining the surface would require minimal metal removal to obtain a fault free, raised surface.

Practical Applications of Padding

This technique is useful for reclaiming worn surfaces, either with standard electrodes or with purpose made hard surfacing electrodes for improved wear resistance. If the wear has been caused by corrosion then corrosion resistant alloy electrodes can be deposited to extend the working life.

In either case a suitable weld surface might be used to extend the anticipated life of a new component, often with the strength

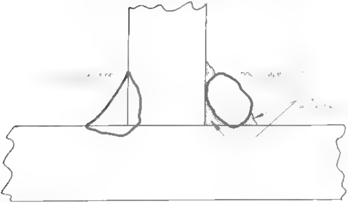
MAKING WELDED JOINTS

Most joints encountered in MMA w are fillet joints, where the weld is place 90 degree corner, without any gap joints are less common and more diffic do we

An edge meeting a surface presents culty in gas welding but MMA is muc sensitive to this sort of variation. Diss thicknesses are not a problem either, pr ed that the thinner piece, or the one ne least heat, is not melted uncontrollabl all welded assemblies the items need arranged in position, probably held clamps, and tacked.

Tacking

The size and number of tacks neede learned with experience. Each should least 6mm long and they should get lo



arcing so that the tack can blend in rather than build up in a 'blob' under the electrode end. It helps further if the electrode is one size smaller than that to be used on the job and the current is set 20 per cent too high

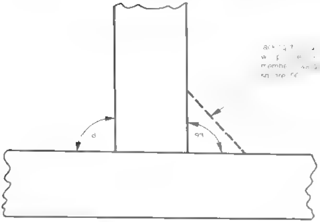
and again, blend in

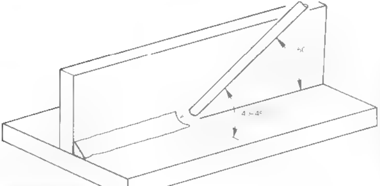
All tacks should be welded through and

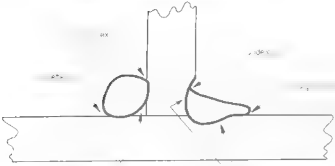
Occasionally tacks crack because they accommodate the shrinkage that take during cooling. This is most likely wh

under high restraint. In this case us trodes with a higher strength ductilit

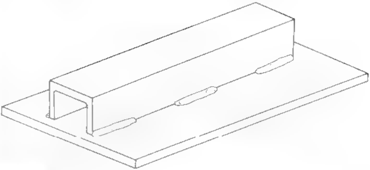
T Fillet Joints







Size and Quantity of Welding

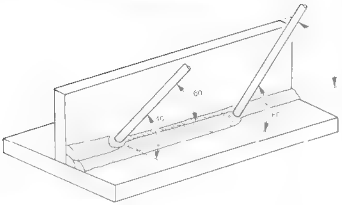


deslag beads between t

at load which makes r

Outside Corner Joints

A 'close' corner joint is one where the pl
touch with at a gap. If full strength is ne
ed then both edges are fully exposed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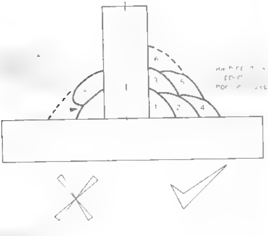
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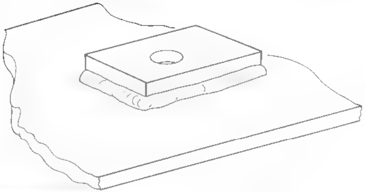
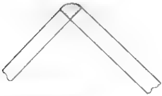
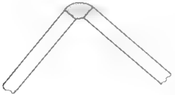
3
5
1
2
4







Butt joints

required, and the joint may be close
chamfered
m plates are butted together, without
nd a single pass is made along the
e then the weld will not penetrate
the full thickness. The strength may

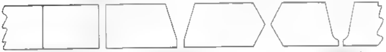
angle iron together to produce the
rk of a workbench, but the tensile
will be well below that of plain 6mm
either leaving a gap or by running a
both sides the strength is much
d
eld metal thicker than 6mm fully

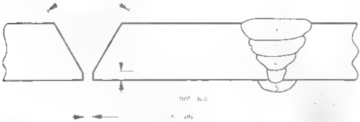
from one side the edges need to
fered at 30–35 degrees, to form
angle of 60–70 degrees when pla
er. This can be done with gas cu
ment either by hand or with
machine or mechanically w
pedestal grinders or nibblers t
produce chamfers.

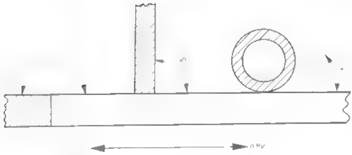
Finally the leading edge of the
removed to form a root face see

Single V Butt Joints

Single V butt joints are more



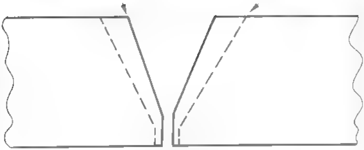




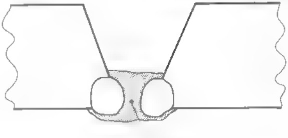
Easy tacking of butt joints

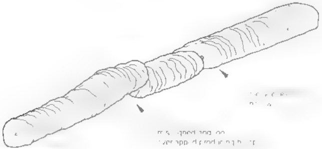
Root Runs

Root Stop Starts



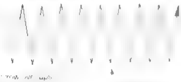
Effect of profile on ease of penetration

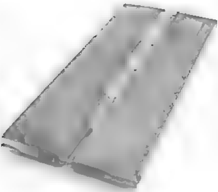


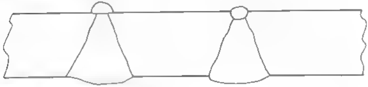


Filling up the V

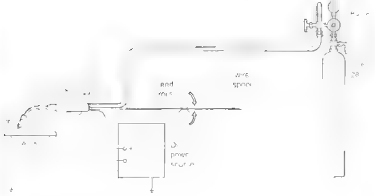
Dealing with Faults







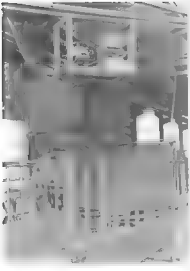
5 MIG WELDING



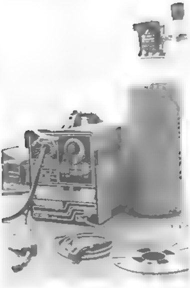
The MIG welding circuit

EQUIPMENT REQUIREMENTS FOR MIG WELDING

Power Source



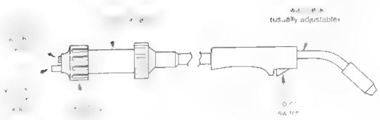
An industrial MIG welding situation with wire feed unit mounted on an overhead boom



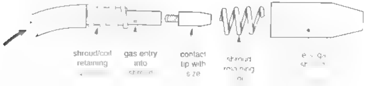
The Welding Lead Assembly

The Welding Torch

MIG Welding Tips



The MIG welding lead assembly



The MIG welding torch

The tip is surrounded by a welding shroud, whose function is to direct gas towards the weld pool. The diameter varies with torch

demand for shielding gas. They are made of copper to withstand heat and general wear

Spool of Wire

Spool sizes are 1kg, 2kg, 5kg, and 15kg, the

and they tend to be made to a high specification in order to be suitable for a range materials. Thus wires are available for carbo

um and its alloys and so on.

There are four main sizes 0.6mm, 0.8m 1.0mm and 1.2mm. The wires are alt fir but the range of kg lengths that can be pr duced is great, ranging from 2mm with 0.6mm wire to 1.0mm with a 1.2mm one

The Wire Feed Unit

[illegible]	[illegible]	Butt			Fillet		[illegible]
		Current amps	Arc voltage	Wire feed speed M/min	[illegible] amps	A[illegible]	[illegible]
[illegible]	[illegible]	80	19	3.2	[illegible]	2[illegible]	
[illegible]	[illegible]	90	20	4.0	11[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	7.0	1[illegible]	2[illegible]	
[illegible]	[illegible]	140	[illegible]	7.5	200	[illegible]	
[illegible]	[illegible]	[illegible]	27.5	7.9	280	18	
[illegible]	[illegible]	2[illegible]	2[illegible]	10	[illegible]	[illegible]	

[illegible]

Shielding Gas

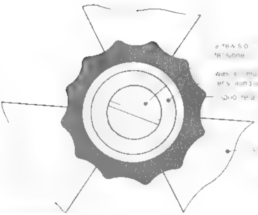
A shielding gas is supplied to the welding area to displace the air and provide a controlled atmosphere. Only aluminium and nickel and their alloys are best welded with a totally inert gas. All other metals use a mixture of gases, typically argon based but with varying additions of carbon dioxide, oxygen, helium or hydrogen.

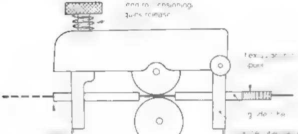
Disposable or small rechargeable canisters are expensive to run as stated earlier. Industrial cylinders vary from 2,300 litre

MAINTAINING/REPLACING EQUIPMENT

Welding Plant

Modern welding rectifiers are very relial[illegible] and with the exception of a cooling fan h[illegible] no moving parts. The only maintenan[illegible] possible or necessary is periodic removal [illegible] dust and metal particle build-up inside [illegible] machine. This is done with compressed [illegible] but ensure that a[illegible] the air is dry and dir[illegible]





Welding Lead Assembly

Excess wear in the liner produces erratic feeding of the wire, which indicates need for replacement. To remove it, extract the wire from the liner, disconnect the euro connector at the machine and withdraw the liner from the connector.

The liner is either a helically coiled flexible metal tube or a Teflon tube, the latter has a shorter life but unlike the metal tube does not clog with chafed wire particles, especially with soft aluminium wire.

Welding Torch

The welding tip wears rapidly and then ceas

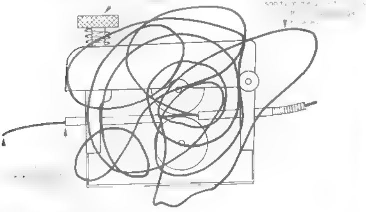
Shroud

These are a sliding fit over a helical coil and require replacement because they are dented or worn to direct gas properly. Alternatively, the coil may cease to grip shroud.

ASSEMBLING THE EQUIPMENT

Loading the Spool

The spool is loaded ensuring that the peg on the wire feed unit is located in a drive hole. It must be put on the right way round so that the wire feeds directly



The wire feed rolls with entangled wire

The wire is drawn off the spool and pushed through the liner via wire feed rolls which form part of the feed unit. One roll is smooth faced while the other has a groove to suit the wire diameter. Rolls typically are designed to drive two wire sizes, either 0.6mm and 0.8mm, or 1.0mm and 1.2mm, so the roll must be mounted correctly in order to ensure use of the correct groove.

... the free wire end is fed into the ... guide tube, on through the open ... and into the euro connector guide tube.

... dropping it in the groove.

... carefully ... but always ... pressure. The rolls must grip the wire well enough to pull ... spool but ... the wire is protected from ... the rolls ... on the wire ... wire feed would result in the wire ... of the roll assembly and ... pattern. If this happens the ...

... to ... If the tip is ... this stage ... the tip is slipped over the ... and screwed home.

PREPARING TO WELD

The wire type and size are selected ... installed and the gas type and flow set ...

Setting the Gas Conditions

... of 2 per cent oxygen and between ...

Higher CO_2 levels increase the heat ... in the arc but also produce more spatter. ... per cent is recommended for steel ... 5mm thick, and above this thickness ... cent. A universal shielding gas available ... which produces good welds through the range of thicknesses.

The amount of gas needed to provide effective shielding of the weld pool is determined by the shroud diameter, and increases as welding gets heavier. Table ... flow rates are only useful if the flow ... rather than pressure can be measured.

Setting the Electrical Conditions

The three main electrical variables a

1. Arc voltage, which controls the type of metal transfer, arc length and weld profile
2. Wire feed speed, which controls the current as well, one knob turning each up/down, and determines the weld size
3. Inductance, which determines the rate of the current rise through the wire

Obtaining satisfactory welding conditions requires careful balancing of all three parameters, and changing any one will have an effect on the other two, which may then also require adjustment to produce a stable arc. The approximate voltage should be set

The two distinct ways in which the wire melts and transfers to the weld pool are known as dip transfer and spray transfer. The mode of transfer is determined by a combination of voltage and current set for a particular wire. For a given wire size dip transfer is obtained at low current/voltage settings, whilst, providing the welder has sufficient capacity, typically 250A or more, spray transfer is obtained at high voltage/current levels.

Initially the voltage is set at roughly the right level to provide the transfer required, and checked with the voltmeter on the machine (press the volt test button or the torch trigger) or by guesswork based on experience.

Welding conditions for dip and spray transfer

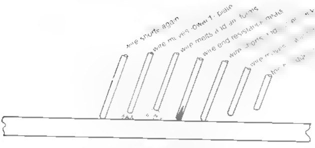
1. The wire advances to touch the plate and complete the circuit
2. The wire heats due to the high current passing through it
3. The end melts and transfers to the metal

4. An arc is established
5. The wire advances and touches the plate

This process is known as dip transfer because the wire keeps dipping in the pool. Although it appears to be constant, the arc exists for only part of the time, with the wire 'short circuiting' the rest of the time. It is a fairly 'cool' method of welding, good for thin metal and welding vertically and over

DIP TRANSFER

Effect of inductance

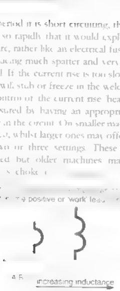


[illegible]

the period it is short circuiting, the wire would melt so rapidly that it would explode out of the arc, rather like an electrical fuse blowing, producing much spatter and very little weld metal. If the current rise is too slow then the wire will stub or freeze in the weld pool.

Control of the current rise 'heating effect' is ensured by having an appropriate inductance in the circuit. On smaller machines this is fixed, whilst larger ones may offer a choice of two or three settings. These are rarely labelled but older machines may identify [illegible] as 'choke' [illegible]

[illegible] may be on [illegible] the positive or 'work' lead [illegible]



Identifying inductance settings

[illegible] circuiting frequency and [illegible] due to the longer ar[illegible] short circuits. The arc [illegible] produce less spatter [illegible] than lower inductance [illegible]

The higher short-ci[illegible] low inductance setting [illegible] and spatter and a [illegible] the weld, but it will be [illegible]

High inductance se[illegible] on thicker metal wh[illegible] unfortunately more [illegible] sheet and positional we[illegible]

Setting Up Dip Transfer

[illegible]

1. Producing a stable [illegible]
2. Supplying the right a[illegible]

3 Supplying the right amount of heat for adequate fusion

MIG welding is notorious for being able to satisfy the first requirement, and by judging the welding speed the second one also, but badly failing to produce fully fused weld

Whilst approximate voltage wire feed speeds can be recommended the final settings can only be established by producing a range of welds, ideally in a simulated situation, and arriving at optimum conditions through trial and error

Arc Voltage Adjustment

With very low settings the arc is so short that the wire may stub, pushing the hand back, and be very erratic. Increase in voltage lengthens the arc to the point where it becomes stable but further increase results in the wire end melting in a ball, this globule eventually transferring to the pool. This is occasionally useful and is known as globular transfer. As the voltage is increased the high, narrow weld profile progressively gets wider and flatter

Wire Feed Speed

The speed at which the wire is fed determines the size of weld, that is, the amount of metal deposited. A larger weld is produced

shorten the arc because the voltage current balance has been altered. It is possible to change either the wire speed or the voltage a little without changing the other, but if the arc is lengthened significantly then an accompanying increase in voltage is necessary to keep the arc stable whilst making the larger weld.

Smaller welds are of course made by turning the wire speed down, and re-balancing the voltage as necessary

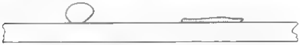
The degree to which the wire speed voltage balance can be raised or lowered is limited by the stability of the arc. Settings which are simply too low for the wire produce a weak arc that fuses poorly. Very high settings produce an arc that is overly forceful, agitating and pushing the weld metal out of place

Changes are required to a smaller and larger diameter wire respectively, so that they operate at current densities that are stable

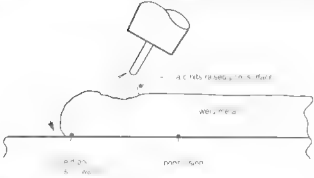
Welding Speed

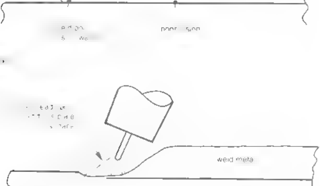
The weld size can be varied by changing the speed of travel but again there are limitations. Very large weld beads can be made in a single pass and may appear to be good and

really to be far less effective than supposed. In a destructive test, or if failing in service, the joint would have a fracture surface exhibiting lack of fusion in the root and the



... weld bead





of course exceed the capacity of the welder, or a 1.2mm wire may already be in use, in which case a number of smaller runs should be used in preference to a single large one.

The difficulty arises in recognizing that lack of fusion is occurring, so professional training and quality control are essential to ensure sound welds.

SPRAY TRANSFER

With voltages above 25V the wire melts differently. Once the arc is established, it is permanent, that is, the wire does not dip into the pool and short-circuit. This mode of transfer is therefore unaffected by inductance setting.

At high voltage wire feed levels fine molten droplets form at the end of the wire

arc is continuous this method is suited to making large well-fused welds on thick metal, but is too hot for thin or positional work.

Setting Up for Spray Transfer

Voltage/Wire Speed Setting

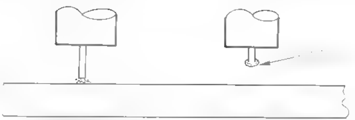
after initial arcing. The arc is very intense and particular attention should be paid to protection against arc burn eye.

FOR BOTH TYPES OF TRANSFER

Initially the voltage is set roughly to prov the type of transfer required and at a level suit the wire diameter: larger wires requ higher voltages.

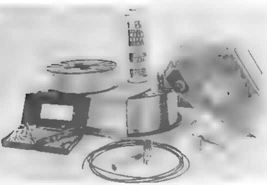
It is important to set the wire 'high', a slowly reduce it, because if it is low (and voltage high) the wire will melt back onto tip instantly. One second of attempted we ing is then followed by a period of 3–5 m utes of 'maintenance'. The fused up end m mean the tip has to be replaced, and if torch switch was not released quickly then the wire may have burst out of the wire feed roll mechanism. Both situations are frust ing, testing the welder's patience and was

It will be apparent that the arc length be changed by an alteration to either the v age or the wire feed. Which one needs adj



FINAL PREPARATION

MAKING A WELD BEAD



at about 80 degrees to ensure maximum use of the gas shielding. A too acute angle causes:

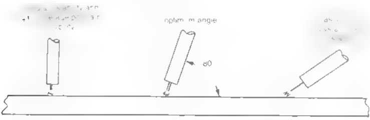
1 Ingress of air into the shielding gas, drawn in by the moving gas. This can also happen if the gas flow is set too high and results in scummy welds and porosity, often visible on the surface

tivity to changes in distance or slightly jerky movement of the torch

The Self-Adjusting Arc

It will be found that if the contact tip height

difference to the length and stability of the

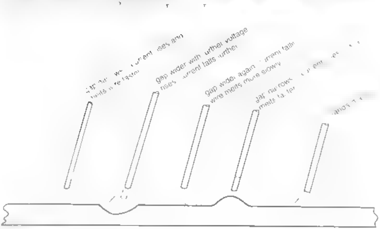


Effect of MIG torch angles

difficult than MMA to ... quickly until the arc length readju

the arc is illustrated

Finishing a Weld Bead



2 Closing the gas cylinder valve.
3 Unwinding the regulator pressure adjust

MAKING WELDED JOINTS

Much of the skill in making good joints is in setting the welder correctly and it is useful to have a similar joint on which to practise and evolve the best welding conditions before commitment to the actual task. This practice is essential until the operator has both experience and familiarity with the machine.

Tacking

Tacking with MIG is very much easier than with either gas or MMA welders. When tacking with gas the joint edges can expand some

be prevented or allowed for

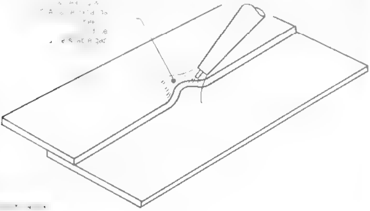
MMA tacks are made ... striking can be difficult, ... flashes over the metal surface ... joint out of position if it is ... well enough

When tacking with MIG ... touch the point at which the ... and on pressing the torch s... very quickly. Like MMA tacks ... along the joint is necessary to ... blend in rather than build up

Fillet Joints

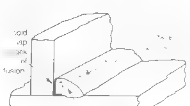
Stringer beads are deposited ... 90 degrees and a tilt of 45 deg... lagble allowance for either gr... ilar thicknesses.

The leading edge of the wel...



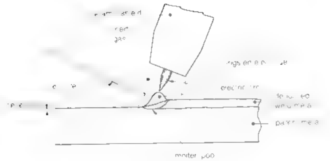
FAULT FINDING IN MIG WELDS

Fault	Cause
[illegible]	[illegible]



Porosity and cold lap in MIG welds

6 TIG WELDING

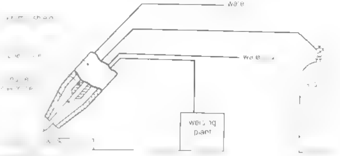


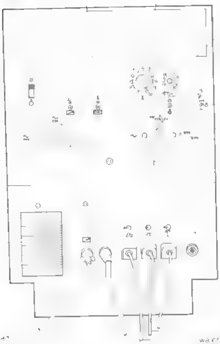
EQUIPMENT REQUIREMENTS

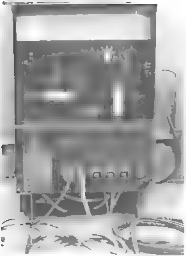
DC TIG Sets

AC TIG Sets

Features of TIG Welding Sets





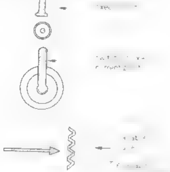


Polarity Switch

Contactor Switch

The polarity switch

Current Control



Foot P

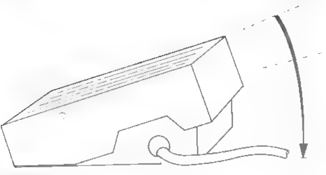
Interm

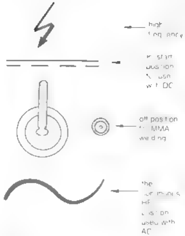
HF Sw

Foot Pedal

External Switch

HF Switch





Gas and Water Control

Lift TIG or Scratch Start

Economizer

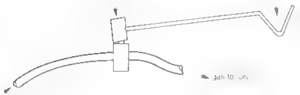
... desired height in a gas ...

Assembling the Equipment

Assuming the welder has a ... supply, the torch assembly ... the welder. The fittings us... symbols or are self ...

Slope In – Out Settings

... lding the arc reaches fu... ramth, and is extinguished ... lope in' enables th... ... be level set over ... and similarly the ...



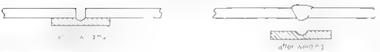
EQUIPMENT MAINTENANCE

PREPARING THE WORK

Cleaning

Edge P

PREPARING TO WELD



The Tungsten Electrode

... with AC

20-30° point. Thoriated for heavy metals with DC

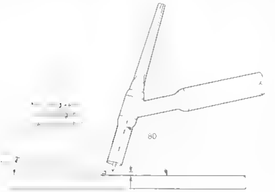
Maximum current density should be aimed for with the smallest electrode that can be used without it melting. If the diameter is too large the arc wanders around the electrode end without focus and is difficult

The diameter of the ceramic shroud is varied to provide enough gas at a flow rate high enough to displace the air. Economy dictates that the smallest possible is used with the lowest flow rate that adequately protects the weld pool.

Gas protection can be improved by using a gas lens which is located inside the shroud giving the gas directionality and much clean

MAKING A WELD BEAD USING DC

The torch is held at 80 degrees, pointing in the direction of travel, with the pointed end of the tungsten about 2mm above the sheet surface. The filler wire is placed on the sheet surface about 10mm away in readiness to add it to the pool and where it can be seen in the light of the arc.



TIG torch angles

Factors Affecting the Qu...

Welding Current

Welding Speed

can be kept under control, fast manual speeds are desirable because these produce the least distortion.

Arc Length

This is very susceptible to variation as the weld progresses, but the variation can be reduced by using the 'pencil' grip. Holding the torch from underneath, perhaps with the edge of the gloved hand sliding along the sheet surface, is much more controllable than the 'power' grip (hand above the torch) used in gas welding.

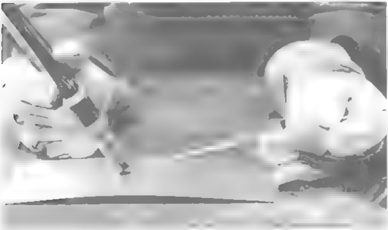
Long arcs cause the arc to spread widely, with wide, shallow melting because of the drop in current. Since the shroud-to-work distance also increases this may allow ingress of air and subsequent contamination of the weld. The arc should be as short as possible, but when it is too short contamination of the electrode is likely, through touching down on the work or misdirecting the wire into the narrow arc gap.

Restarting the Bead

Some types of stainless steel in particular may oxidize in the crater enough to necessitate grinding. Otherwise simply ensure that the crater surface is fully melting before adding filler and progressing.

Finishing the Weld Bead

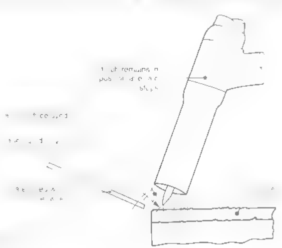
At the end of the bead the crater is filled in to prevent weakness/cracking at this point. This is done by topping up with filler wire and is easier if the current is made to decay gradually, either with slope out or with the foot switch.



The best TIG torch grip for bench work

MAKING A BEAD USING AC

SHUTTING DOWN PROCEDURE



back to the packet or, if uncertain about their identity, scrapping them.

MAKING TIG WELDED JOINTS

Most of the principles of producing good TIG welds have already been established and it should now simply be a matter of applying them and (a) following a joint line and (b) supplying the right amount of heat/filler to produce a sound bead with a good profile.

Tacking

Tacks are made easily enough but the metal may distort either as it is heating or as a result of tacking. The amount of restraint required to prevent this happening will be learned

The care over cleanliness and fusion when welding is also required during tacking since the tacks are to become fused into the weld

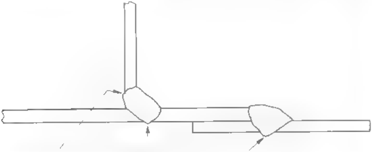
joint as they are approached and th accomplished most easily on V prep using 'bridge tacks'. As the name im these are built up from each side until

The bridge tack

form a bridge across the upper part of t thus aligning the plate while still being ea

Fillets

In common with other welding processe weld pool should be observed to fuse into the corner at the leading edge and up in the desired profile at the tr



railing edge. Some regulation of the current speed may be necessary to prevent the ...eld breaking through the unwelded side of

The minimum requirement of any fusion ...at is that it should be fused to all of the ...rent metal it is in contact with, but the bal

B. ...

welding, the po... and the arc ... Establishing a ...

the metal thick... sight sinking ... penetrating, fi...

7 WELDING OTHER METALS

COPPER

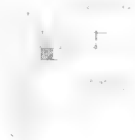
ALUMINIUM

Oxy Acetylene Welding

MMA Welding

MIG Welding

ensuring a smooth feed when using a soft aluminium wire.



The push-pull gun

TIG Welding

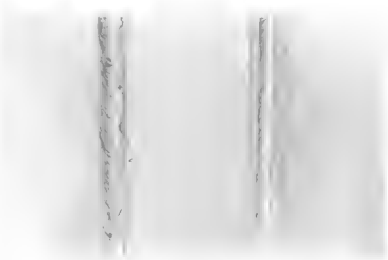
TIG welding is a little sl... guaranteed quality a... choice of filler wires to... alloy MIG and TIG wel... argon shielding gas.

STAINLESS STEELS

There are many alloys w... known as stainless steel... of three groups

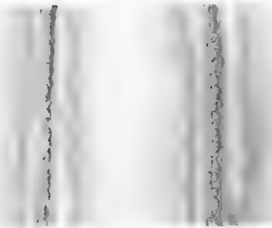
1. Martensitic

3. Austenitic



A MIG bead (left) and a TIG bead (right) on the surface of aluminium sheet

The Consumables



so on, but fails critically and prematurely when put into service because the weld metal composition and hence its physical properties are wrong.

Heat Input

This will be kept as low as possible in order to reduce crystalline change and growth in the heat affected zone. Welding must be done as quickly as possible and the work may need to be allowed to cool down between main runs.

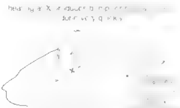
Expansion/Contraction

Tacking frequency
Heat input
Weld sequence

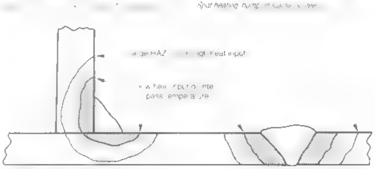
Choosing the Welding Process

Oxy-Acetylene

A suitable filler and flux for st... required and a fair degree ... process has now completely g... TIG process



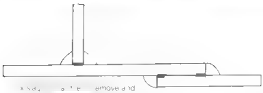
Spot heating

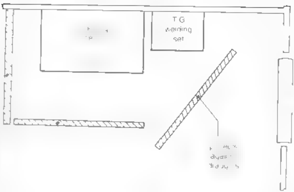


MMA

MIG MAG

TIG





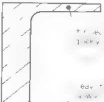
Site plan of TIG welding screens

CAST IRON

tems of complex shape and varying thicknesses but these are likely to heat cool at very different rates. Combined with its low ductility, this makes cast iron very susceptible to cracking unless great care is taken to both heat and cool the metal evenly. The problem is aggravated by the high carbon content, which makes the metal even more brittle if cooled quickly.

Welding Procedure

Strip down to a 'single' component at



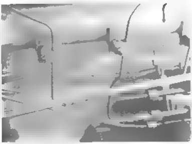
Heating/cooling rates affected by

Preheating

Gas Braze Welding

Arc Welding

MMA



Gas Fusion Welding

MIG

TIG

Studding

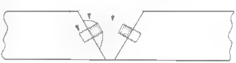
The strength of thicker joints is improved by studding. Holes are drilled into the joint surface, tapped, and studs inserted. These are

DISSIMILAR METALS

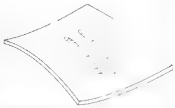
Welding is not possible between the light alloys and the 'heavy' ones, so, for example, a mechanical method or an adhesive is the way to join stainless steel to aluminium.

Otherwise, if one or both metals is stainless steel, then the filler should match the stronger, higher alloyed material. Dissimilar carbon steels can be welded with a low hydrogen electrode, whilst non-fusion welds are best for combinations of brass, copper and steels.

buttered surfaces, one or both, with high nickel rod

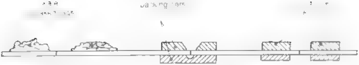


8 DISTORTION CONTROL



Warping of sheet

BUCKLING



...ess volume of heat into the metal so MIG welds heat the metal less than gas ...mes an... large MMA electrodes less than smal...

Alternatively a very low heat source can be used and/or welding can be stopped periodically for the metal to cool as necessary before recommencing.

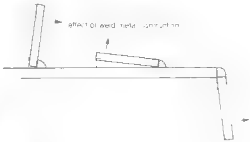
ANGULAR DISTORTION

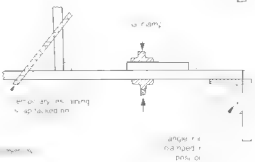
1500°C and it cools ...

This is compared b...

the movement to pr...

Restraint





Restraint can be built in by tacking as many items together as possible before starting to weld so that one piece of metal holds others in place. This can be achieved artificially by tacking on cross braces or diagonals, welding up and then removing the braces afterwards.

Controlled Movement

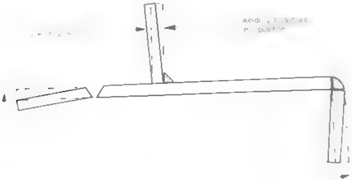
ed and used to advantage

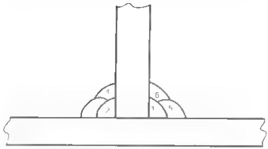
Presetting
If a fillet is expected to pull over about 5 degrees, then setting it back 5 degrees before starting will cause it to be in the correct alignment when welded. Judgement is difficult for one offs but some presetting must improve the accuracy.

Weld Sequence
This is perhaps the most important and interesting method at the w... welding on one side pulls direction then welding on pull it back again. The both times be opposite and at or to the previous weld but it ed to counteract the pull not make it twice as bad w... not completely pull bac second side may require before returning to the beads are placed so that th the direction required.

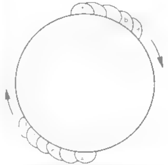
DESIGN

If welding produces d expensive then welding s minimum. Joint location reduce the volume of weld possible practical weldin anced rather than one sid





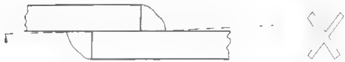
Welding on opposite sides to counteract contraction



[illegible]

Welding on adjacent sides to counteract distortion

[illegible]



9 QUALITY IN WELDING

The overall performance of a welded joint will depend on four factors:

1. The type of material being welded
2. The consumables used to hold it together
3. The procedure used to make the joint
4. The skill of the welder making the joint

In order to have confidence and reliability in welded work standards are applied in all four areas, typically national ones like DIN in Germany, and BS in Britain, but moving rapidly towards ENs in Europe. Euro Norms are becoming universal across the EC and in Britain are prefixed by BS, for example, BS EN 10 025 is the standard applied for structural steels.

Materials and consumables are subject to quality control during manufacture to ensure compliance with various standards. Welding procedures and the welder's skill are assessed by making and testing specimen welds, which vary in difficulty to reflect particular areas of work. The welder is the most vulnerable part of the system, as his performance may be influenced by many factors. However, working to an established weld procedure should ensure that the joint is not distorted and that the weld is of the correct chemical composition and metallurgically acceptable in terms of ...

The weld must also be physically sound, fully fused with the parent metal it is in contact with, have no discontinuities or inclusions and a profile which blends smoothly with the plate.

WELD FAULTS AND THEIR CAUSES

Lack of Penetration

The weld fails to fuse fully into the root of a fillet or through a butt joint. Probable causes ...

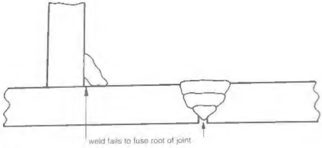
1. More heat is required — use a larger flame or higher current setting.
2. Less filler is needed — use a smaller electrode, lower wire feed speed, or in gas TIG welding feed less in.
3. The joint gap is too small or the angle is ...

Over Penetration

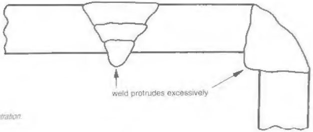
The weld metal protrudes excessively through a butt or breaks through the other side of fillets. The causes are the opposite of those listed above for lack of penetration.

Lack of Fusion

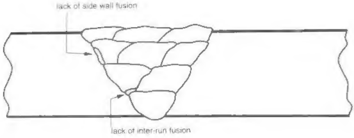
The weld metal fails to fuse at the interface



Lack of penetration



Over-penetration



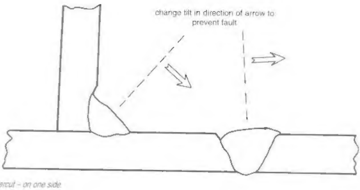
Lack of fusion

This has the same causes as lack of penetration and can be avoided by using more heat/less filler.

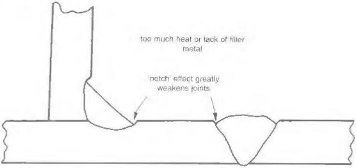
Undercut

The metal has melted away but has not been filled in, leaving a 'notch' at the side of the weld. Undercut on one side only indicates that the angle of tilt (of the torch/gun) did not bisect the joint angle.

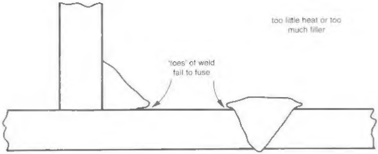
If it appears on both sides then the ratio of heat to filler must be reduced, that is, less heat or more filler is needed.



Undercut – on one side.



Undercut – on both sides.



Overlap.

Overlap

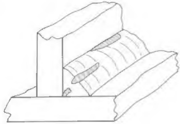
Not common, this is where weld metal spills over the plate surface without having fused to it. When this occurs on one side only, a change in tilt angle is needed, but if it happens on both sides then more heat or less filler is required.

Cold Lap

This is a term applied to MIG welding only but actually means lack of fusion/overlap. It is very difficult to eliminate completely, at restarts generally and at those in aluminium in particular. Higher voltage/wire settings are required or less wire/more voltage.

Slag Traps

These occur in MMA welding only and are voids in the weld metal occupied by slag. The causes are numerous and include a low current setting, acute preparation angle, steep electrode slope angle, or welding over slag or heavy scale.



Slag traps.

Porosity

Gas entrapment is rarely evident on the weld surface, but the traps' spherical form appears as light circles on an X-ray. This problem is caused in stick welding by damp electrode coatings (hydrogen) or in MIG/TIG welding by lack of gas shielding, or from contaminants such as oil and oxide scale.

Blowholes

These are gas holes large enough to appear

on the weld surface and may be due to extreme porosity, or in braze welding occur as a result of too little oxygen in the flame.

Underfill

Part of a butt weld is below the plate surface, causing it to fail any welding test. More filler/passes are required.

Spatter

Particles of weld thrown out on the plate surface, caused by high welding currents, long arcs and damp electrodes in MMA welding, and by too little inductance/too much CO_2 in the shielding gas in MIG welding.

Rough Appearance

Erratic arc length, long arcs and shallow slopes give rise to rough welds, as do damp electrodes and surface contamination.